ENTRY PREVENTION THROUGH STRATEGIC CAPACITY EXPANSION AND PRICING

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Abstract

In this paper, market and cost data from the titanium dioxide industry are used to analyze firm limit pricing. One firm in that industry had a cost-reducing technological advantage over all others. By strategically expanding its own capacity, this firm could have established an equilibrium market price -- or limit price -- that would have prevented its rivals from expanding. The method of achieving this goal and the method's feasibility are discussed.

In the early 1970s it became evident that E.I. DuPont de Nemours and Co. had become the low-cost producer of titanium dioxide -- a whitening and voidhiding agent. DuPont had developed a new, secret production process which had significantly lower production costs than the other technologies used in the industry. DuPont believed that no other titanium dioxide producer could emulate its new process for some time -- perhaps until as late as 1985. Given this advantage, DuPont sought to capture all growth in market demand for the intervening years.

In 1977 the Federal Trade Commission filed a complaint against DuPont, charging it with attempting to monopolize in violation of Section 5 of the Federal Trade Commission Act. The Commission contended that DuPont was using its cost advantage to establish an unfair limit-pricing policy. A direct result of this policy would have been DuPont's acquisition of a monopoly share of the market.

This discussion uses data collected in the Federal Trade Commission's case to see how DuPont could have established a limit-pricing policy. Market conditions that would have made expansion by a firm other than DuPont unprofitable are explored and related to actions DuPont might have taken. Also examined is the profitability of these hypothetical actions for DuPont.

Section 2 of this paper is a description of the titanium dioxide industry in the early 1970s. The general nature of the industry is described, along with the actions DuPont could have taken, given that nature, to establish its limit-pricing policy.

Section 3 formally develops the limit-pricing model. This model determines a yearly equilibrium market price that would have denied DuPont's competitors any incentive to expand their own productive capabilities. An integral part of this model is the translation of these yearly limit prices into required DuPont capacity expansions.

In Section 4 the data to be used in the limit-pricing model are briefly described. All data are derived from documents taken from the Federal Trade Commission's case against DuPont.

Section 5 presents results of the model. The limit price and its associated capacity expansion requirements are given under certain parameter assumptions. Then the effects of parameter changes on these results are discussed.

Finally, the overall profitability of DuPont's limit-pricing strategy is evaluated. This section is followed by a general conclusion.

Section 2: The Titanium Dioxide Industry

The titanium dioxide industry can best be described as an oligopoly. In 1972 there were six major firms in the industry, each with a significant market share. All firms recognized their interdependence throughout the period of interest, and knew that significant output changes by one would affect the market price and thus the profitability of all others. The industry in general has produced a homogeneous product for which there have been no commercially satisfactory, directly interchangeable substitutes providing comparable value-in-use. Three alternative production processes have been used in the industry. Each produces titanium dioxide by reacting an agent, either chlorine gas or sulfuric acid, with a titanium bearing feedstock. The first process developed to produce titanium dioxide was the "sulfate process." In the 1950s, firms began to use a second process, called the "rutile chloride process." DuPont began research and development on a third production process in the 1940s. Eventually DuPont's efforts were successful and by 1960 DuPont was operating two commercially viable "ilmenite chloride" or "advanced chloride" plants. DuPont has held its ilmenite chloride technology secret.

DuPont developed its new advanced chloride process for several reasons. One was greater feedstock flexibility. With its new process, DuPont could use a variety of readily available feedstocks. Another reason for developing the advanced chloride process was waste disposal. Chloride plants require a much smaller investment in waste treatment facilities than do sulfate plants.

As a result of market conditions,

by 1972 it became apparent that DuPont's new technology enjoyed a significant cost advantage over others. Unlike other producers, DuPont did not have to buy scarce and expensive feedstocks, nor did it have to incur pollution-related capital investment costs. As long as certain feedstocks remained scarce and expensive and environmental regulations forced high pollution abatement costs, DuPont, by virtue of its secret ilmenite chloride technology, would be the industry's low cost producer.

If, in 1972, DuPont had indeed wanted to take advantage of its position as low cost producer by setting up a limit-pricing strategy, how would it have done so? Any plant a competitor might have built would have used a relatively inefficient technology. Any of DuPont's competitors could have built a new plant by cross subsidizing expenditures from other corporate revenues or by borrowing against corporate assets.[1]   Whether they would have done so depended on how profitable they expected expansion to be. All firms required a minimum return on any capital investment. If a possible expansion project was not expected to provide a minimum rate of return, it was not built. Thus DuPont could have prevented its competitors from expanding by ensuring that the expected rate of return on expansion was too low to make it worthwhile.

The rate of return on plant investment is directly related to the market price for the plant's output. At full capacity, a relatively high market price will bring a relatively high rate of return; a low market price will bring a low rate of return. If DuPont could have established a low enough market price for titanium dioxide, perhaps it could have made the rate of return on a competitor's contemplated expansion project unacceptably low.

The market price for titanium dioxide is tied to demand and supply

conditions in the industry. Suppose DuPont could have expanded its own supply to drive down the equilibrium market price. If DuPont had expanded enough, it might have been able to drive the market price to a level that would not allow a return to justify a competitor's expansion.

By virtue of its cost advantage, DuPont might have been able to establish a successful limit-pricing policy. DuPont might have used increments in its own supply to establish a market price too low to allow a reasonable rate of return to any competitor contemplating expansion, yet high enough to justify DuPont's own expansion. The choice of this entry-preventing price and its associated supply and capacity adjustments is derived in section 3.

Section 3: Limit Pricing Model

The limit price is the highest market price DuPont could have established which would make expansion appear unprofitable to a competing firm. With this in mind, consider the situation a competitor faced in building a new plant. For the plant under consideration define:

CCNP = Capacity of a Competitor's New Plant
K = 1972 cost of building that new plant
N = Number of years that plant would have a useful life
i = Internal rate of return
TR_t = Tax rate in period t
C_t = Unit cost of sales in period t
P_t = Price in period t
DEP_t = Depreciation in period t
NR_t = Net revenue in period t
NTI_t = Net taxable income in period t
TAX_t = Taxes due from operation in period t
$NIAT_t$ = Net income after taxes in period t
$NUCF_t$ = Net undiscounted cash flow in period t

Then the following can be derived for that plant:

$NR71+t$ = $(P71+t - C71+t)CCNP$
$NTI71+t$ = $NR71+t - DEP71+t$
$TAX71+t$ = $TR71+t * NTI71+t$
$NIAT71+t$ = $NTI71+t - TAX71+t$
$NUCF71+t$ = $NIAT71+t + DEP71+t$

A competitor would have no incentive to expand if the internal rate of return from expansion were less than some minimum level. Let that level be described as i*. Then, to prevent a competitor's expansion, DuPont would want the following inequality to hold:

$$(1) \quad \sum_{t=1}^{N} \frac{NUCF71+t}{(1+i^*)t} - K < 0.$$

The sum of net cash flows, discounted at the critical rate, should be just outweighed by the cost of construction. In other words, to prevent a competitor from expanding, DuPont would want the net expected present discounted value of expansion to be negative.

DuPont would want to accomplish this by using a limit-pricing policy. From the definitions above, it can be shown that:

$$(2) \quad NUCF71+t = z1 P71+t - z2 + z3$$
with $z1 = (1-TR71+t)CCNP$
$z2 = C71+t * (1 - TR71+t)CCNP$
$z3 = DEP71+t * (TR71+t).$

Equation (2) clearly shows that net cash flows to a competitor are a function of the current equilibrium market price. If DuPont could have forced a low market price, it could have reduced a competitor's net undiscounted cash flows. Relating this to equation (1), had DuPont been able to reduce a competitor's net cash flows, it could have prevented that competitor's expansion project from being built.

By increasing its own capacity,

DuPont could have increased the market supply of titanium dioxide, thereby forcing a low market price for titanium dioxide. Equations (1) and (2) show that a low market price could prevent a competitor from expanding. Thus, the key to DuPont's entry-preventing strategy would be its policy of increasing its own capacity.

Begin the process of calculating the capacity expansions that would allow DuPont to prevent entry by looking at the market demand for titanium dioxide. Demand in general can be described as a linear function. Documents in the case make it clear that demand was expected to grow at about 3 1/2 percent per year through 1985.[2] Given this information, the general form of the demand function, describing demand in any period as a function of that period's price, would be:

$$(3) \ Qd71+t = (A - BP71+t)eat$$

where Qd is demand in tons, P is price per ton, a equals 0.034, and A and B are demand parameters.

Now turn to the supply side of the market. Supply in any year can be any amount less than or equal to productive capacity. Capacity in any year is equal to capacity carried over from the previous year plus any capacity built in that year. The name-plate capacity at the end of 1971 for each type of plant was as follows: DuPont's name-plate capacity was about 287,000 tons; its competitors' rutile chloride name-plate capacities at the same time totaled about 138,000 tons; these competitors' sulfate name-plate capacities totaled about 400,000 tons.

DuPont believed that by 1980 three of its competitors' sulfate plants, with a total name-plate capacity of 168,000 tons, would be forced to shut down.[3] Since it is impossible to predict exactly when these plants would have closed, their loss can be described by an exponential function. Then sulfate capacity

(SC) in any year can be described as:

$$(4) \ SC71+t = 400,00ebt$$

with b = -0.0605 through 1980 and sulfate capacity equal to 232,000 tons thereafter.

Assuming that the limit-pricing policy would have been effective in preventing the expansion of a competitor's capacity, the total existing capacity (TEC) in any year would then equal DuPont's 1971 existing capacity plus its competitor's 1971 existing chloride capacities (these two total 425,000 tons) plus sulfate capacity in that year, or:

$$(5) \ TEC71+t = 425,000 + SC71+t$$

Define CCNP (Capacity of a Competitor's New Plant) as the capacity of a new plant a competitor was contemplating building. Note that CCNP is a constant representing the capacity of the first plant any competitor might have built. If DuPont could have established a limit pricing policy to prevent this plant from being built, it certainly could have prevented any similar plant from being built.

Define CDNP71+t (Capacity of DuPont's New Plants) as the aggregate capacity of any new plants DuPont built after 1971. (So if DuPont had added 50,000 tons of new capacity in 1974 and 100,000 tons more of new capacity in 1976, CDNP76 would have equaled 150-,000 tons.) Now define Qs71+t, potential supply in period t, as total existing capacity (or what is left in period t of capacity that was in place in 1971) plus any new capacity DuPont may have built between 1971 and period t (CDNP71+t), plus the capacity of a competitor's new plant, or:

$$(6) \ Qs71+t = (TEC71+t + CDNP71+t + CCNP) * 0.95.$$

The right hand side of equation (6) is multiplied by 0.95 to constrain

75

supply to be equal to productive capacity, because productive capacities generally equal at most 95 percent of name-plate capacities. Variables inside the parentheses represent name-plate capacities.

By equating demand (equation (3)) to supply (equation (6)) it is possible to solve for the equilibrium market price. This equilibrium price can be written as a function of DuPont's capacity additions, and is shown in equation (7) as:

(7) $P_{71+t} = q_1 + q_2 + q_3 CDNP_{71+t}$

where $q_1 = \dfrac{A - 0.95\, TEC_{71+t}e^{-at}}{B}$

$q_2 = \dfrac{-e^{-at}}{B}\, 0.95\, CCNP$

$q_3 = -0.95\, \dfrac{e^{-at}}{B}$

Equation (7) shows that the equilibrium price in each period is a function of any increments in capacity made by DuPont. This relationship provides a mechanism by which DuPont could have forced the equilibrium market price to its desired limit price.

Following equation (7), DuPont could have adjusted its capacity to affect the equilibrium market price. By equation (2), the market price would then have affected net undiscounted cash flows to a competitor from its contemplated new plant. By equation (1), for a given minimum required internal rate of return, net undiscounted cash flows would have determined whether the net present discounted value of that plant was positive or negative. By strategically choosing its yearly capacity levels, and therefore its yearly supply levels as well, DuPont could have made the expected present discounted value of a new plant negative and could have prevented its construction. DuPont could have used limit

pricing, established by capacity expansion, to prevent a competitor from building a new titanium dioxide plant.

Solution of this limit pricing model requires making certain assumptions about net undiscounted cash flows. Clearly a competitor's decision to expand rests on its expected future cash flows. Estimates of future flows depend, in part, on current future cash flows, and the trend in recent past cash flows.Therefore, a reasonable path for the limit price to follow may have been one that (1) ensured that the discounted net cash flow in each year is the same across years, so a competitor will see no trend of increasing flows, and (2) ensured that the sum of these cash flows, discounted at the critical rate, would be just less than the cost of construction. Then there would have been no trend in cash flows to make a competitor expect greater flows toward the end of the project's life, and at the current rate of flows, the project would not have been attractive.

Section 4: Data

The data needed to solve this limit-pricing model are briefly described below.

CCNP = 50,000 tons = Capacity of a Competitor's New Plant
K = $49,190,000 = 1972 cost of building that plant
N = 13 = Useful life of plant
i* = 10% = Minimum required rate of return
TRt = TR = 53% = Tax rate in year t

In 1971, approximately 707,000 tons of titanium dioxide were shipped domestically, at a price of $408 per ton.[4] Demand parameters A and B can be found by substituting these figures into equation (7) and assuming a demand elasticity of 0.1.[5]

Unit cost of sales represents the

76

average cost of producing and selling one unit of output from a plant. It can be broken into two components: ore costs and all other costs. If each component is assumed to increase at some rate over time (where these rates are represented by d1 and d2), the unit cost of sales to a competitor in any year can be described as:

ORE   ALL OTHER

$$(8) \quad C71{+}t = COST72 \, (1{+}d)t{-}1 + COSTS72 \, (1{+}d)t{-}1$$

By regressing capacity data for existing plants on cost-of-sales data and on ore-cost-as-percent-of-total-cost data, it is possible to estimate the 1972 ore cost for a new 50,000 ton rutile chloride plant as 7.25 cents per pound of output, and all other costs in 1972 as 13.7 cents per pound of output.

Depreciation is calculated by use of the Class Life Asset Depreciation System (ADR).[6] This involves double-declining balance for the first year and sum-of-years'-digits in all other years.

Section 5: Limit Pricing Results

With these parameters in hand, it is possible to estimate the limit price and DuPont's associated capacity expansions. The limit price, under certain parameter assumptions, is shown in table 1. The additions to capacity that DuPont would have had to make to establish this limit price as the market price are likewise shown in this table.

Table 1 shows that the limit price increases over time. Because unit cost of sales and undiscounted net revenue needs for a competitor's contemplated new plant would have increased every year, undiscounted gross receipts would have had to increase each year as well. However, output from a competitor's contemplated new plant would have been constrained by plant capacity. Therefore, to increase gross revenues, a competitor would have needed a higher price. If the competitor needed a higher price in order to break even, then of course the price at which the competitor would not have broken even -- the limit price -- had to rise as well.

According to table 1, to have established its requisite limit price in any year, DuPont would have had to increase its capacity in any year by the amount shown in column 4. Notice that capacity increments are much greater in earlier than later years. This is attributable to the interaction of two forces. In all years, demand was steadily increasing; however, in early years (1973 through 1980) the industry was losing sulfate capacity. Thus, from 1973 to 1980 DuPont would have had to make up for lost capacity and meet increasing demand. After 1980, Du-Pont's only concern would have been meeting increasing demand.

Suppose some parameter estimates are incorrect. How would this change the results in table 1? The limit price will increase when any cost parameters increase. Again, with potential output for a new plant limited to capacity, the higher revenue needed to cover higher costs would have to be earned by an increase in price. As the price needed to generate sufficient revenue rises, the highest price that would not generate sufficient revenue must rise as well. A similar argument holds for the limit price falling as cost parameters fall.

If the critical discount rate, i^*, falls, the limit price also falls. This model constrains discounted cash flows to be constant over time. A falling i^* would allow the firm to earn less before discounting and still meet its revenue requirement.

The effect of a change in K, the cost of a new plant, is not as easily determined. An increase in K will increase required cash flows, and this will act to drive up the limit price.

However, an increase in K will also drive up depreciation allowances. This will decrease taxes, increase revenues, and force down the limit price. The total effect depends on the year under consideration, the interest rate, and the plant's depreciable life.

Equation (7) shows that the limit price is inversely related to DuPont capacity expansions. Therefore, any parameter changes that force up the limit price will require DuPont to expand less to establish its limit-pricing policy.

The final step in this analysis is to determine the profitability of DuPont's limit-pricing strategy. Table 2 shows the 1972 capacities of each of DuPont's plants and the increments to capacity each plant could have received to bring its ilmenite chloride production line capacity up to feasible maximum limits.

Combining this information with the results in table 1, it seems that DuPont's best strategy for establishing its limit pricing policy would have been to have 78,000 tons of additional capacity in place at its New Johnsonville plant by 1974, and 67,000 tons of additional capacity in place at its Edge Moor plant during 1976. In addition, DuPont would have wanted to have one production line (110,000 tons) operating at a new site by 1978 and a second line there by 1981. These capacity expansions would have been necessary to establish a successful limit-pricing strategy.

The expansion needs described above have been derived from the requirements of the limit-pricing policy, without regard to their profitability. It is difficult to exactly measure the profitability of the policy taken as a whole. An internal rate of return for the entire capacity expansion plan will possess several roots given the stream of positive and negative cash flows associated with expansion. DuPont's

new plant would have been the largest plant built and would have used the most advanced and lowest cast technology in the industry. It would probably have had an economic life of several decades. This would have made calculating an internal rate of return very difficult.

However, to shed some light on the profitability of DuPont's strategy, the internal rate of return can be calculated on the individual DuPont plant expansions proposed above. By estimating expansion and production costs, and using the limit price in table 1, the internal rate of return on the New Johnsonville expansion, through 1985, would have been about 30 percent; on the Edge More expansion, about 20 percent. These projects would have been profitable.

One measure may help to determine the overall profitability of the suggested method for achieving DuPont's limit-pricing goals. Estimating construction costs, expansion costs and net undiscounted revenues from 1973 to 1985 for all expansion -- both for enlarging existing plants and for building the new plant's first and second lines -- and discounting annually at 10 percent, the net percent discounted value of the entire expansion project in 1985 would have been roughly 40 million dollars. Expansion, taken as a whole, would have paid for itself by 1985. Any net revenues earned after that point would have been profit.

Conclusion

These results show that DuPont could have used a limit-pricing strategy to prevent a competitor from building a new, inefficient plant. The limit pricing model describes a path price could follow to successfully prevent entry. This price path has been translated into DuPont capacity expansion needs, and it has been shown that DuPont could have made these capacity expansions profitably. Clearly, if in 1972 DuPont had

claimed an intention to expand its existing capacity and to build a new, large and efficient plant, any competitor would have had to regard these expansions as leading to a market price -- or limit price -- that would have left it no incentive to build its own new plant.

Epilogue

While DuPont did seem to pursue a limit-pricing policy through the 1970s, things did not work out as planned.

The 1974-1976 recession forced actual demand significantly below projected levels. In addition, as oil prices increased, the cost of chlorine increased. This drove up DuPont's production costs and decreased its cost advantage. As of 1981, DuPont had only one line operating at its new plant. While other manufacturers have expanded their existing plants somewhat, none has built a new plant. Whether this is a result of DuPont's actions or a downturn in the market is not clear.

FOOTNOTES

1. In 1972, Kerr McGee, the smallest, had sales of $603,254,000, assets of $762,50-4,000, net income of $40,689,000 and ranked 207th in Fortune's top 500. Source: Fortune, "Fortune's Top 500", May 1973.

2. Complaint counsel exhibit 27E.

3. In complaint counsel exhibit 27L, DuPont produced a table showing 1971 capacities of all its competitors' plants. As a footnote, its author wrote, "Sulfate process plants for SCM (Glidden) (50M TPY), Am. Cyanamid (70M TPY), and Gulf and Western (N.L. Inc.) (40M TPY) are not included in this table because it is assumed that they will be forced out by environmental and other considerations."

4. Actually, several different grades of titanium dioxide are produced. This price is the weighted average price for all grades produced.

5. The cost of titanium dioxide makes up a small part of the production cost of final products in which it is used. There are no reasonable substitutes with comparable value-in-use. Manufacturers of products that use titanium dioxide may choose to use less of it as input, but in some cases this would adversely affect their products' quality. In its trial brief, the Federal Trade Commission estimated that the elasticity of demand, for titanium dioxide may be as low as 0.05. All this points to a fairly inelastic demand for which 0.1 seems a reasonable estimate.

6. Commerce Clearing House, 1977 Federal Tax Course, pp. 1311-1312.

Table 1
Limit Price and DuPont Capacity Expansions

Year	Limit[1] Price	Additions to Capacity[2] Aggregate	Incremental
1973	22	0	---
1974	25	9,219	9,219
1975	28	49,344	40,125
1976	31	88,272	38,928
1977	33	125,987	37,715
1978	37	162,451	36,464
1979	40	197,612	35,161
1980	43	231,394	33,782
1981	47	250,074	18,680
1982	51	266,959	16,885
1983	55	282,621	15,662
1984	59	297,741	15,120
1985	64	311,922	14,181

1 In cents per pound of titanium dioxide produced.
2 In tons.

Table 2
1972 DuPont Plant Capacities and Allowable Increments
to Bring Ilmenite Capacities up to Proposed Limits

Plant	Production Process	1972[1] Capacity (tons)	Allowable Capacity Additions (tons)	Proposed[2] Ilmenite Capacity (tons)
Antioch	Rutile Chloride	27,000	--	27,000[3]
New Johnsonville	Ilmenite Chloride	150,000	78,000	228,000[4]
Edge Moor	Ilmenite Chloride	45,000	67,000	112,000
	Sulfate	55,000	--	55,000[5]

1 Source: Chemical Economics Handbook, Chemical Information
   Service, Menlo Park, California, June 1978.
2 Source: Complaint Counsel Exhibit #27I, "Sales Forecast and
   Planned Capacity," from 1972 White Paper.
3 This plant would remain a rutile chloride plant.
4 This would be two production lines, each 110,000 tons.
5 This line would be converted to 55,000 tons of chloride
   capacity.

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